

Estimate of Vigor Classes of *Brachiaria Ruziziensis* using Sensors Boarded on UAV Platform

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Keywords — *Forage, UAV, Remote Sensing, Vegetation index.*

Abstract — *Traditional procedures for biomass estimation usually use destructive methods with great demands on time, resources, and labor. The development of models for automated estimation of pasture biomass, particularly from images captured by Unmanned Aerial Vehicle (UAV), in addition to high spatiotemporal resolution combined with flexibility in image acquisition, provides agility, the economy of resources, and labor. The objective of this work was to establish a technical feasibility study for the use of multispectral sensors onboard an Unmanned Aerial Vehicle (UAV) to estimate the vigor classes of *Brachiaria ruziziensis* pastures. For this purpose, imaging cameras in the visible (RGB), near-infrared and red edge ranges were used for continuous monitoring of 20 pasture paddocks with an area of 1,350 m² each, totaling 27,000 m² of the experimental area. The indices performed well and were sensitive in class discrimination at intervals that range from soil exposure and stresses caused by pest and disease infestation (low vigor) to conditions in which the vegetation is in good development, in class intervals with high levels of vegetation and, consequently, pointing to high values of biomass.*

I. INTRODUCTION

The non-destructive and appropriate monitoring of the biophysical characteristics of the plants is paramount in evaluating their physiological and phenological conditions and, consequently, in better understanding their functioning over time [1]. Some of the most relevant biophysical characteristics to be monitored characterize the efficiency with which light, water, and nutrients are captured and used for biomass production [2].

Remote sensing techniques have been used for decades to monitor vegetation. However, in the last years, the interest in the use of automated techniques and procedures with a good spatial and temporal resolution to monitor plant growth and development [3, 4, 5] has increased.

The remote sensing satellite images usually lack high spatial resolution, therefore the details of plants or small

plots of field plantations can be observed. In addition, it can also be poor in terms of temporal resolution, that is, the frequency of revisiting combined with the possible occurrence of clouds limits the use of satellites for detailed agricultural applications when there is a need to monitor the crop at daily scales or in critical periods to optimize decision-making. In this context, unmanned aerial vehicles (UAVs) can be an interesting alternative as they offer high spatial and temporal resolution and proper imaging coverage.

Technological advances in UAVs platforms and cost reductions have been the major factors in the increase in the use of this platform for civil purposes. The UAV technology, in addition to allowing pre-programmed and automated flights with the aid of a global positioning system (GPS), can contribute to filling the knowledge gap between the leaf and the canopy by considerably

improving the spatial and temporal resolution of the commonly used air transport systems of remote sensing [6]. This technology has stood out in the so-called smart farms, showing efficiency in collecting data to extract knowledge that enables more accurate assessments of crop conditions [7].

Imaging sensors onboard UAVs can collect data both in the visible range (RGB sensors) and in the near-infrared and thermal ranges. Multispectral cameras, for example, enable the extraction of information in different bands of the electromagnetic spectrum. Sensors onboard of UAV platforms enable the generation of spectral indices and other products such as digital terrain model (DTM), 3D modeling, image orthomosaic, volume estimation, and precise contour lines.

Given the above, the objective of this work was to establish a technical feasibility study for the use of multispectral sensors onboard an Unmanned Aerial Vehicle (UAV) to estimate the vigor classes of *Brachiaria ruziziensis* pastures.

II. MATERIAL AND METHODS

Study area characterization

The study area is located in the municipality of Coronel Pacheco, state of Minas Gerais, Brazil, more precisely in the José Henrique Bruschi Experimental Field (CEJHB) of Embrapa Dairy Cattle. Regarding the terrain, the municipality of Coronel Pacheco, MG, has 10% flat terrain, another 10% considered mountainous, and 80% undulating terrain. The maximum and minimum altitudes are 1,070 m and 409 m, respectively. The head of the city has an altitude of 484 m. The experimental area was at an altitude between 424 and 465 m. the soil in the area is predominantly a clayey-textured dystrophic yellow latosol (Figure 1).

According to the Köppen-Geiger climate classification, the municipality of Coronel Pacheco, MG, is located in a transition zone of climate classification Aw (tropical climate with a dry winter season) and Cwa (temperate humid climate with dry winter and hot summer). However, the Cwa-class predominates in the region of the municipality where the weather station of the National Institute of Meteorology (INMET) is located. Based on INMET climatological standards for the period from 1981 to 2010, the annual average air temperature is 21.4°C and the average annual precipitation volume is 1620.6 mm. July (12.6 mm) and January (355.1 mm) are the months with the lowest and highest rainfall, respectively.

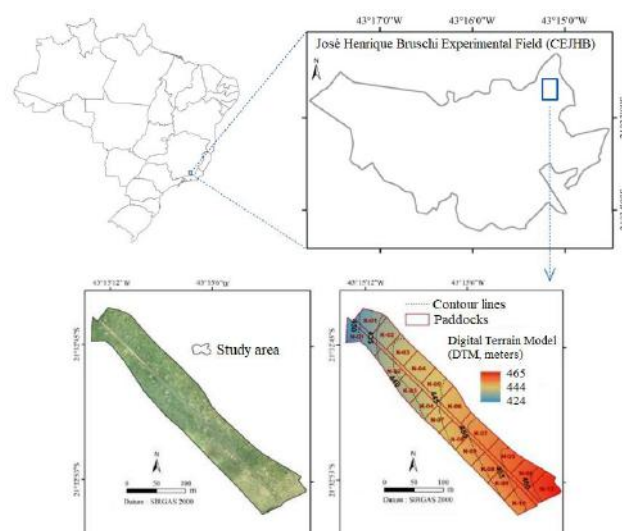


Fig. 1: Location of the study area highlighting contour lines, delimitation, and identification of *Brachiaria ruziziensis* experimental paddocks, municipality of Coronel Pacheco, Minas Gerais, Brazil.

Cultural practices and animal management

Grasses of the species *Brachiaria ruziziensis* (cv. BRS Integra and cv. Kenedy) were established in December 2017, in a 6-ha area. The soil was amended with limestone to raise the base saturation to 40%. After plowing and harrowing, forages were planted in rows spaced 40 cm, with a sowing density of 3.5 kg of viable pure seeds per hectare. At planting, a dose of 100 kg/ha of P_2O_5 was applied. Nitrogen and potassium were applied at a dose of 40 kg/ha, 50 days after planting. The area was split into two sub-areas. The first three hectares were intended for the management of reserve animals and the second, with also three hectares, was used in the conduction of the experiment.

The area under the management of the experimental animals was split into two 1.5-ha sub-areas, which were again split with an electric fence into 20 paddocks, 10 of which were used for each grass. Rotated stocking management was adopted and the switch-back experimental design for evaluating milk production was used. Grazing was carried out by Holstein x Zebu cows, during the rainy season (October to May) of 2017-2018 and 2018-2019. The average idle period was 18 days and the paddock occupation was of two days. The average heights of the forage canopy at the entrance and exit of the animals from the paddocks were 50 and 25 cm, respectively. The cows were provided by the herd owned by Embrapa Dairy Cattle. The pastures received annual doses of 200 kg/ha of N and K_2O and 50 kg/ha of P_2O_5 .

Aerial surveys for generation of vegetation indexes

The aerial surveys were carried out on November 14, 2018, January 14, 2019, and May 13 2019 using a rotary-wing UAV, quadcopter-type, model Inspire 1 Pro and with the use of a Sentera Multispectral Double 4K Gimbaled – 5 band camera, according to the specifications shown in Table 1.

Table 1: Specifications of each band of the spectral range were obtained with the use of Sentera Multispectral Double 4K Gimbaled imaging

Bands	Wavelength center (nm)	Band width (nm)
Blue	446	60
Green	548	45
Red	650	70
NIR	720	40
Red Edge	840	20

The flight plans were carried out following standardized technical compliance, so that the results or products of the aerial survey could be compared on similar bases, equalizing variables such as flight height, pixel size of ground images (Ground Sample Distance - GSD), sensor calibration, percentage of image overlap, wind speed, brightness, shadow/sun positioning, time of day, angle of view, etc.

The flight plan was parameterized as follows: (i) flight height of 90 m; 2.60 cm GSD; maximum speed of 4.5 m/s, flight time of 20 minutes using two batteries; 75% lateral and frontal overlap of the images. Based on this flight plan configuration, 18 flight lines and 229 images were needed to cover the entire area and later generate the orthomosaic through processing in the Pix4D Mapper Pro 4.125 software.

Using the images containing the five spectral bands specified in Table 1 enables to perform the analysis of planting conditions through the application of vegetation indices. These indices can be an aid in the classification of the targets, for example, in the discrimination of vegetation growing within the normal range and planting areas with some type of deficiency [8].

This experiment used the VARI (Visible Atmospherically Resistant, [8]), GLI (Green Leaf Index, [9]), and CIgreen (Green Chlorophyll Index, [10]) indices. The indices NDVI (Normalized Difference Vegetation Index, [11]) and NDRE (Normalized Difference Red Edge, [12]) were also used.

$$VARI = \frac{\rho_{Green} - \rho_{Red}}{\rho_{Green} + \rho_{Red} - \rho_{Blue}} \quad \text{Eq. 1}$$

$$GLI = \frac{(2 \rho_{Green} - \rho_{Red} - \rho_{Blue})}{(2 \rho_{Green} + \rho_{Red} + \rho_{Blue})} \quad \text{Eq. 2}$$

$$CIgreen = \left(\frac{\rho_{nir}}{\rho_{green}} \right) - 1 \quad \text{Eq. 3}$$

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \quad \text{Eq. 4}$$

$$NDRE = \frac{\rho_{nir} - \rho_{rededge}}{\rho_{nir} + \rho_{rededge}} \quad \text{Eq. 5}$$

Where ρ_{Green} , ρ_{Red} , ρ_{Blue} , $\rho_{RedEdge}$ and ρ_{NIR} are the spectral bands corresponding to the Green, Red, Blue, Red Edge, and near-infrared (NIR) channels, respectively.

III. RESULTS AND DISCUSSION

Figures 2 and 3 show an RGB mosaic image (Figures 2A, 3A) and maps of the VARI (Figures 2B, 3B), GLI (Figures 2C, 3C), CIgreen (Figures 2D, 3D), NDVI (Figures 2E, 3E) indices and NDRE (Figures 2F, 3F) from the study area with grasses of the species *Brachiaria ruzizienis* (cv. Kenedy – paddock K-01 and cv. BRS Integra – paddock N-01), for November 14, 2018. Figure 2 shows a table with the range of classes of the indices and their respective estimates of area (ha) and percentage (%) of coverage concerning the total area of the paddock.

The VARI is an index whose formulation seeks to reduce possible influences of atmospheric constituents. The GLI index has been applied to distinguish between photosynthetically active vegetation and dry vegetation with soil exposure. CIgreen seeks to highlight aspects relevant to green vegetation. Originally developed to enhance herbaceous-shrubby vegetation, the NDVI is one of the most used indices in different vegetation studies. On the other hand, the NDRE has been used to distinguish shades between forages with different vigor conditions and the noise represented by the soils.

The Natural Breaks (Jenks) algorithm was used to establish the ranges of vegetation index values classes, in which five classes were defined represented by two palettes in shades of green (dark and light) and another three in the colors of yellow, orange, and red. The color palettes in shades of green represent the plants ranked with the highest values of the vegetation indices.

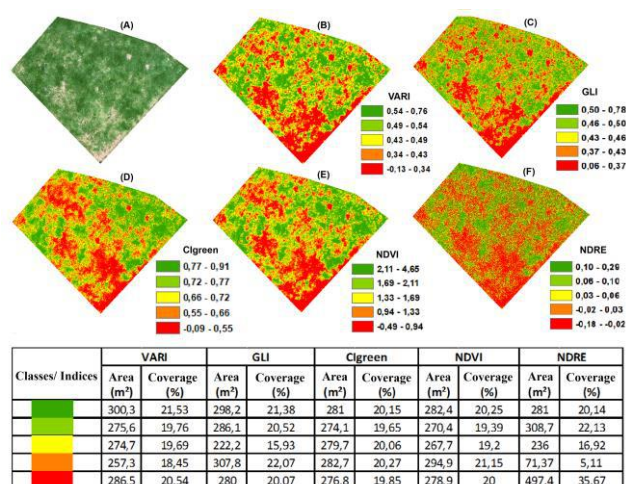


Fig. 2: RGB mosaic image (A) of the *Brachiaria ruziziensis* - cultivar Kennedy K-01 paddock area with maps of vegetation indices: VARI (B), GLI (C), CIgreen (D), NDVI (E), and NDRE (F), for November 14, 2018.

Plants with greater vigor (shades of green) were classified as 41.29%, 41.90%, 39.80%, 39.64%, and 42.27% of the *Brachiaria ruziziensis* - cultivar Kennedy paddock area by the VARI, GLI, CIgreen, NDVI, and NDRE indices (Figure 2), respectively. On the other hand, in the low vigor class represented by the red color palette, the VARI, GLI, CIgreen, NDVI, and NDRE indices showed covers of 20.54%, 20.07%, 19.85%, 20%, and 35.67 %, respectively.

Regarding cultivar BRS Integra from the N-01 paddock, (Figure 3), about 46.48%, 41.20%, 21.57%, 55.68%, and 33.97 of vegetation cover were classified as plants with greater vigor (shades of green) when VARI, GLI, CIgreen, NDVI, and NDRE indexes were applied, respectively. In this case, according to the index used, a large percentage of difference is observed in the estimates of greater-vigor vegetation cover.

According to established intervals, the CIgreen and NDRE indices were those with the lowest percentage of area defined as a vigorous plant-class (dark green class), in which plants classified as intermediate predominated. On the other hand, the NDVI index had greater saturation, that is, it was less sensitive in discriminating classes with high vigor and, therefore, it overestimated the coverage percentage of this class of plants (Figure 3).

Figure 4 shows a cutout area of the K-01 paddock (cv. Kennedy) that exemplifies the sensitivity of the NDRE (Figure 4A) and CIgreen (Figure 4B) indices. The CIgreen index showed good sensitivity in identifying vegetation stresses, however, it did not demonstrate the sharpness, detail, and separation of classes offered by the NDRE

(Figure 4A). This fact is observed when comparing the regions highlighted in circles in Figures 4A and 4B.

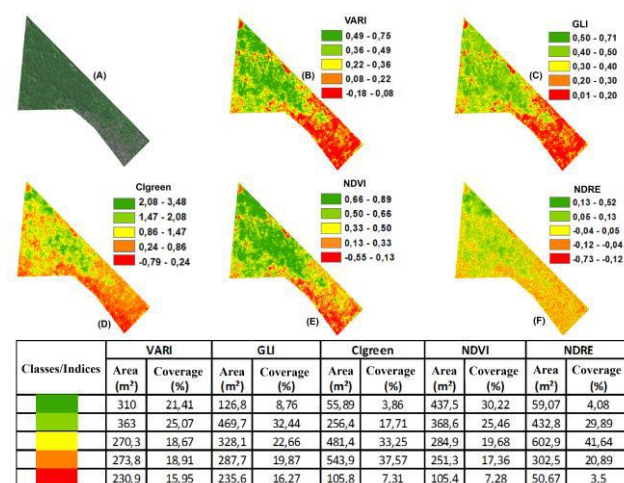


Fig. 3: RGB mosaic image (A) of the *Brachiaria ruziziensis* - cultivar BRS Integra N-01 paddock area and maps of the vegetation indices: VARI (B), GLI (C), CIgreen (D), NDVI (E), and NDRE (F), for November 14, 2018.

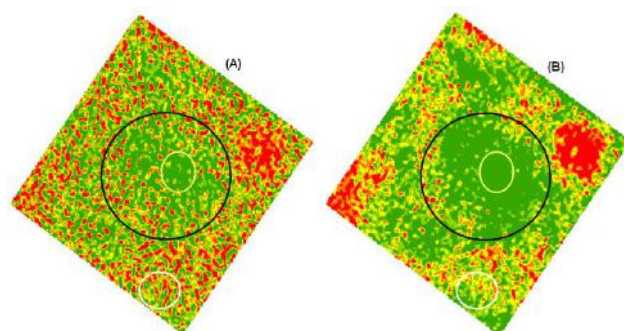


Fig. 4: Cutout of the K-01 paddock (cv. Kennedy) area exemplifying the detection sensitivity of the NDRE (Figure 4A) and CIgreen (Figure 4B) indices.

Figure 5 shows RGB mosaic and the application of the NDVI (Figures: 5B, 5E) and NDRE (Figures: 5C, 5F) indices of *Brachiaria ruziziensis*, cultivars Kennedy (Paddock K-06: Figures: 5A, 5B, 5C) and BRS Integra (Paddock: N-06: Figures: 5D, 5E, 5F), on January 14, 2019. It is observed that the NDRE index was able to distinguish details in the scene.

In comparison to the NDVI, the NDRE detected a slightly higher percentage of more vigorous plants, approximately 2%, represented by classes in shades of green. It detected a lower percentage of stressed plants and non-plants (exposed soil, animal feces, and others), with approximately 2.5%, represented by classes in yellow and reddish shades. The greatest difference observed between

them, approximately 15% greater, is because of the classification of dead plants and non-plants, represented by the red class. However, it is observed that the sum of the orange and red classes, which represent highly stressed plants (with difficult recovery) and non-plants, had percentage estimates of around 40%. The presence of leafhoppers (*Deois flavopicta* - Hemiptera: Cercopidae) significantly impacted the area cultivated with *Brachiaria ruziziensis* and caused a reduction in vigor and, consequently, in the expected production capacity.

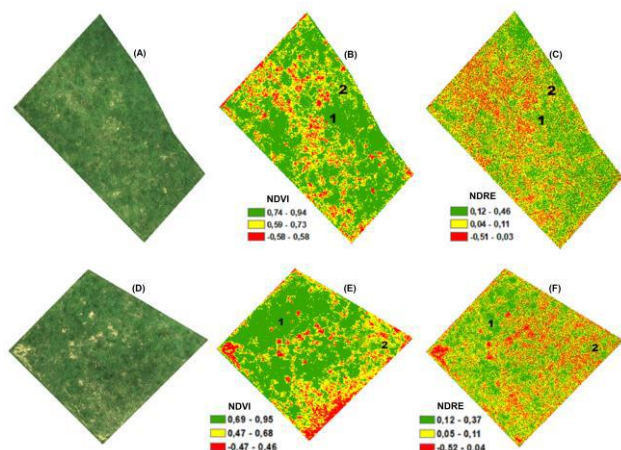


Fig. 5: RGB mosaic image (Figures 5A, 5D) and maps of the NDVI (Figures: 5B, 5E) and NDRE (Figures: 5C, 5F) indices of *Brachiaria ruziziensis*, cultivars Kennedy (Paddock K-06: Figures: 5A, 5B, 5C) and BRS Integra (Paddock: N-06: Figures: 5D, 5E, 5F), corresponding to the aerial survey carried out on January 14, 2019.

Figures 6, 7, and 8 show RGB mosaics (Figures 6A, 7A, 8A; 6D, 7D, 8D) and the NDVI index maps (Figures: 6B, 7B, 8B; 6E, 7E, 8E) and NDRE (Figures: 6C, 7C, 8C; 6F, 7F, 8F) of *Brachiaria ruziziensis*, corresponding to the aerial survey carried out on May 6th (Figure 6) and 13th (Figures 7 and 8) of 2019.

The indices point to a spatiotemporal heterogeneity of development of *Brachiaria ruziziensis* within each paddock area with cultivars Kennedy and BRS Integra. In this case, several factors may have influenced, such as conditions of the water, grazing, chemical, and physical soil constituents, and pest attacks such as leafhoppers. In this case, it is clear that the vegetation indices can help to identify areas of the plantation that present development within the normal range or with some deficiency. According to Hunt Jr. et al. [9], vegetation indices have fundamental application in extracting information from remote sensing data, however, these methods may reduce, but not eliminate, the effects of soils, topography, and angle of view.

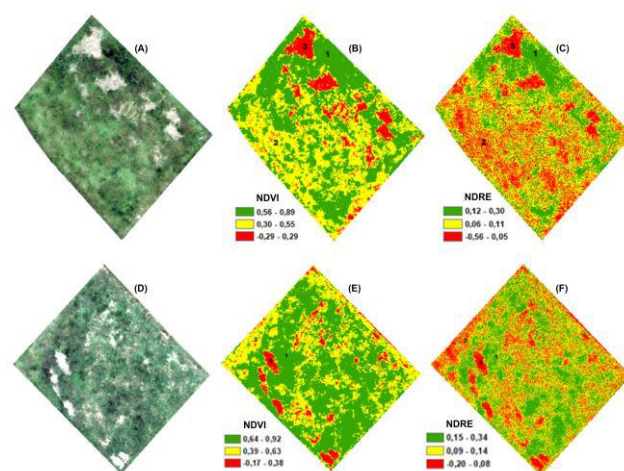


Fig. 6: RGB mosaic image (Figures: 6A, 6D) and maps of the NDVI (Figures: 6B, 6E) and NDRE (Figures: 6C, 6F) indices of *Brachiaria ruziziensis*, cultivars Kennedy (Picket K-03: Figures: 6A, 6B, 6C) and BRS Integra (Picket: N-03: Figures: 6D, 6E, 6F), corresponding to the aerial survey carried out on May 6, 2019.

The NDRE is more efficient in discriminating or interpreting plant conditions from the intermediate stage of development, that is, when the plant accumulates a large number of overlapping leaves. This index better captures the reflectance of the lower layers of the canopy leaves that are photosynthetically active. In this case, the explanation for the better NDRE sensitivity when compared mainly to NDVI (Figures 6, 7, and 8) is the fact that the red band is better absorbed by the leaves for photosynthesis in comparison to the red edge band (Red Edge).

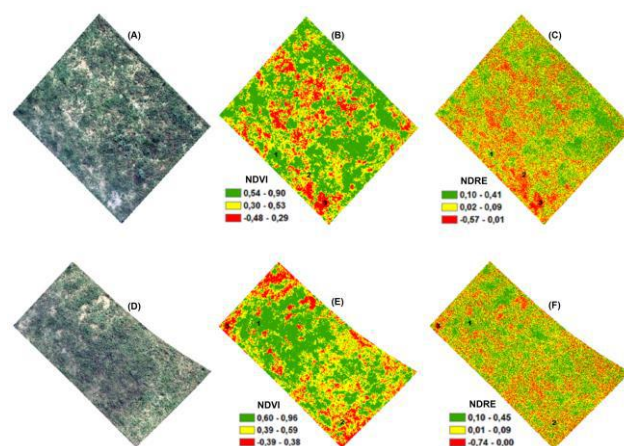


Fig. 7: RGB mosaic image (Figures: 7A, 7D) and maps of the NDVI (Figures: 7B, 7E) and NDRE (Figures: 7C, 7F) indices of *Brachiaria ruziziensis*, cultivars Kennedy (Paddock K-05: Figures: 7A, 7B, 7C) and BRS Integra (Paddock: N-03: Figures: 7D, 7E, 7F), corresponding to the aerial survey carried out on May 13, 2019.

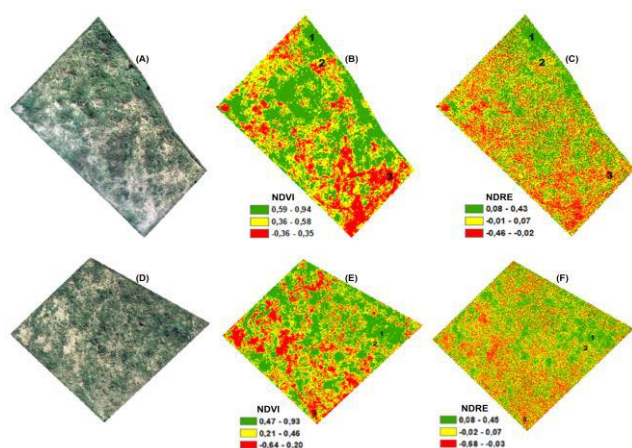


Fig. 8: RGB mosaic image (Figures: 8A, 8D) and maps of the NDVI (Figures: 8B, 8E) and NDRE (Figures: 8C, 8F) indices of *Brachiaria ruziziensis*, cultivars Kennedy (Paddock K-06: Figures: 8A, 8B, 8C) and BRS Integra (Paddock: N-06: Figures: 8D, 8E, 8F), corresponding to the aerial survey carried out on May 13, 2019.

In general, the color of the leaf varies according to the percentage of reflectance of the chlorophyll pigment and the absorbance of visible light in the red, green, and blue spectrum ranges, that is, in the RGB range. However, there are light spectrum bands such as the RedEdge that are more accurate or sensitive to the presence of chlorophyll pigments in the plant. Furthermore, just as near-infrared is widely used in the indication of nitrogen in leaves, the red edge has been very accurate in identifying the variability of nitrogen in leaves. In this context, the use of the NDRE index has great potential for mapping the variability of leaf nitrogen, aiming, for example, for greater efficiency in the application of fertilizers.

IV. CONCLUSION

The indices showed good performance and sensitivity in class discrimination at intervals that point to from soil exposure and stresses caused by pests and disease infestation (low vigor) to conditions in which the vegetation is at a good development, in class intervals with high levels of vegetation and, consequently, indicating high values of biomass. Furthermore, it was observed that the NDRE index has greater sensitivity in identifying shades of vegetation vigor, demonstrating greater clarity and detail in the discrimination of plants under stress conditions.

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